SULFUR POISONING ELIMINATION OF DIESEL ENGINE CATALYST

FIELD OF THE INVENTION

[0001] This invention relates to the elimination of sulfur poisoning of a NOx trap catalyst that traps nitrogen oxides (NOx) discharged by a diesel engine.

BACKGROUND OF THE INVENTION

[0002] JP06-272541A published by the Japanese Patent Office in 1992, discloses an exhaust gas purification device wherein a diesel particulate filter (DPF) that traps particulate matter in the exhaust gas of a diesel engine and a NOx trap catalyst that traps NOx in the exhaust gas, are used.

[0003] The NOx trap catalyst also traps sulfur oxides (SOx) contained in the diesel fuel. This is referred to as sulfur poisoning. When sulfur poisoning occurs, the NOx trap ability of the catalyst decreases.

[0004] In the prior art, the NOx trapped by the NOx trap catalyst is first reduced, next, the DPF burns the trapped particulate matter, and the reducing agent concentration in the exhaust gas is then increased to eliminate the sulfur poisoning.

SUMMARY OF THE INVENTION

[0005] When the reducing agent concentration of the exhaust gas is increased, a large amount of particulate matter is discharged. Therefore, when a long time is

spent on eliminating the sulfur poisoning, a large amount of particulate matter collects in the DPF by the time the sulfur poisoning has been eliminated.

[0006] In general, the diesel engine runs in a lean atmosphere. If a large amount of particulate matter collects in the DPF when the air-fuel ratio is returned to lean for the usual operation after the sulfur poisoning is eliminated, a problem arises. Specifically, if the temperature of the exhaust gas at this time is higher than the self-ignition temperature of the particulate matter, the particulate matter trapped by the DPF burns rapidly. As a result, when the temperature of the DPF exceeds a preferable range for performance, the particulate trap performance of the DPF decreases.

[0007] It is therefore an object of this invention to eliminate the sulfur poisoning of a NOx catalyst while preventing particulate matter from collecting in the DPF.

[0008] In order to achieve the above object, this invention provides a purification device for an exhaust gas of a diesel engine, comprising a catalyst which traps nitrogen oxides in the exhaust gas but decreases a nitrogen oxides trapping performance when poisoned by sulfur oxides in the exhaust gas wherein the sulfur oxides poisoning the catalyst is eliminated by contact with an exhaust gas corresponding to a rich air-fuel ratio, a filter which traps particulate matter in the exhaust gas and burns a trapped particulate matter by contact with an exhaust gas corresponding to a lean air-fuel ratio, an air-fuel ratio regulating mechanism which varies an exhaust gas composition of the engine between a composition corresponding to the lean air-fuel ratio and a composition corresponding to the rich air-fuel ratio, a sensor which detects a particulate matter trap amount of the filter, and a programmable controller.

[0009] The controller is programmed to control the air-fuel ratio regulating mechanism to cause the exhaust gas composition of the engine to be in a state corresponding to the rich air-fuel ratio, determine whether or not the particulate matter trap amount has reached a predetermined amount while the exhaust gas composition is in a state corresponding to the rich air-fuel ratio, control the mechanism to cause the exhaust gas composition to be in a state corresponding to the lean air-fuel ratio, when the particulate matter trap amount has reached the predetermined amount during a period when the exhaust gas composition is in a state corresponding to the rich air-fuel ratio, determine whether or not the particulate matter trap amount has reached a predetermined decrease state during a period when the exhaust gas composition is in the state corresponding to the lean air-fuel ratio, and control the mechanism to cause the exhaust gas composition to be in a state corresponding to the rich air-fuel ratio, when the particulate matter trap amount has reached the predetermined decrease state during the period when the exhaust gas composition is in the state corresponding to the lean air-fuel ratio.

[0010] This invention also provides a method for controlling a purification device for an exhaust gas of a diesel engine. The purification device comprises a catalyst which traps nitrogen oxides in the exhaust gas but decreases a nitrogen oxides trapping performance when poisoned by sulfur oxides in the exhaust gas, wherein the sulfur oxides poisoning the catalyst is eliminated by contact with an exhaust gas corresponding to a rich air-fuel ratio, a filter which traps particulate matter in the exhaust gas and burns a trapped particulate matter by contact with an exhaust gas corresponding to a lean air-fuel ratio, and an air-fuel ratio regulating mechanism which varies an exhaust gas composition of the engine between a

composition corresponding to the lean air-fuel ratio and a composition corresponding to the rich air-fuel ratio.

[0011] The method comprises determining a particulate matter trap amount of the filter, controlling the air-fuel ratio regulating mechanism to cause the exhaust gas composition of the engine to be in a state corresponding to the rich air-fuel ratio, determining whether or not the particulate matter trap amount has reached a predetermined amount while the exhaust gas composition is in a state corresponding to the rich air-fuel ratio, controlling the mechanism to cause the exhaust gas composition to be in a state corresponding to the lean air-fuel ratio, when the particulate matter trap amount has reached the predetermined amount during a period when the exhaust gas composition is in a state corresponding to the rich air-fuel ratio, determining whether or not the particulate matter trap amount has reached a predetermined decrease state during a period when the exhaust gas composition is in the state corresponding to the lean air-fuel ratio, and controlling the mechanism to cause the exhaust gas composition to be in a state corresponding to the rich air-fuel ratio, when the particulate matter trap amount has reached the predetermined decrease state during the period when the exhaust gas composition is in the state corresponding to the lean air-fuel ratio.

[0012] The details as well as other features and advantages of this invention are set forth in the remainder of the specification and are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic diagram of a diesel engine exhaust gas purification

device according to this invention.

[0014] FIG. 2 is a flowchart describing a sulfur poisoning elimination routine executed by a controller according to this invention.

[0015] FIG. 3 is a flowchart describing an air-fuel ratio control subroutine executed by the controller.

[0016] FIG 4 is a flowchart describing an air-fuel ratio control subroutine for regenerating a DPF executed by the controller.

[0017] FIGs. 5A-5E are timing charts that describe changes in an excess air ratio lambda (λ), a sulfur poisoning amount and a particulate matter collection amount due to execution of the sulfur poisoning elimination routine.

[0018] FiG. 6 is similar to FIG. 1, but showing a second embodiment of this invention.

[0019] FIG. 7 is similar to FIG. 1, but showing a third embodiment of this invention.

[0020] FIGs. 8A-8E are timing charts that describe changes in the excess air ratio λ, the sulfur poisoning amount and the particulate matter collection amount under the sulfur poisoning elimination control according to a fifth embodiment of this invention.

[0021] FIGs. 9A-9E are timing charts that describe changes in the excess air ratio λ, the sulfur poisoning amount and the particulate matter collection amount under the sulfur poisoning elimination control according to a sixth embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Referring to FIG. 1 of the drawings, a diesel engine 40 for vehicles rotates due to combustion of a gaseous mixture of air aspirated from an intake pipe 21 via a throttle 41, and diesel fuel injected from a fuel injector 44. The fuel is supplied to the fuel injector 44 by a common rail fuel system.

[0023] The exhaust gas due to combustion is discharged via an exhaust pipe 22. A part of the exhaust gas is recirculated to the intake pipe 21 via an exhaust gas recirculation (EGR) passage 23.

[0024] An exhaust gas purification device 1 is installed midway in the exhaust pipe 22.

[0025] The exhaust gas purification device 1 comprises a NOx trap catalyst 10 which traps NOx (nitrogen oxides) in the exhaust gas, and a diesel particulate filter (DPF) 20.

[0026] The NOx trap catalyst 10 contains a NOx trap agent that traps NOx. As the NOx trap agent, barium (Ba), magnesium (Mg) or cesium (Cs) can be used. The NOx trap catalyst 10 traps NOx contained in the exhaust gas corresponding to a lean air-fuel ratio due to the action of the trap agent. The trapped NOx is reduced by reducing agent components contained in exhaust gas corresponding to a rich air-fuel ratio, under the catalysis of the NOx trap catalyst 10, and is discharged.

[0027] The NOx trap catalyst 10 traps not only the NOx in the exhaust gas, but also SOx (sulfur oxides) as previously stated. When sulfur oxides collect in the NOx trap catalyst 10, the NOx trap ability decreases. This state is called sulfur poisoning. To eliminate the sulfur poisoning, it is necessary to increase the reducing agent components contained in the exhaust gas. For this purpose, it is necessary to make the exhaust gas composition correspond to a rich air-fuel ratio.

[0028] The DPF 20 is installed downstream of the NOx trap catalyst 10. The DPF 20 comprises a ceramic porous filter. The DPF 20 traps particulate matter in the exhaust gas. The trapped particulate matter burns due to the temperature rise of the exhaust gas, and is removed from the DPF 20. In the following description, the raising of the exhaust gas temperature to burn particulate matter trapped by the DPF 20 is referred to as the regeneration of the DPF 20. The regeneration of the DPF 20 is performed using the high temperature exhaust gas generated by the combustion of the air-fuel mixture at a lean air-fuel ratio.

[0029] The elimination of the sulfur poisoning of the NOx trap catalyst 10 and the regeneration of the DPF 20 are both performed by controlling the air-fuel ratio of the burning air-fuel mixture. The air-fuel ratio of the air-fuel mixture is determined by the air amount aspirated via the intake throttle 41 and the fuel injection amount of the fuel injector 44. The opening of the intake throttle 41 and the fuel injection amount of the fuel injector 44 are varied according to signals output by a controller 50.

[0030] The controller 50 comprises a microcomputer comprising a central processing unit (CPU), read-only memory (ROM), random access memory (RAM) and input/output (I/O) interface. The controller may also comprise plural microcomputers.

[0031] The controller 50 determines the fuel injection amount of the fuel injector 44 according to the required load, i.e., for example, according to a depression amount of an accelerator pedal with which the vehicle is provided. In normal operation of the engine 40, the controller 50 maintains the air-fuel ratio of the burning air-fuel mixture at a predetermined lean air-fuel ratio by increasing or decreasing the opening of the intake throttle 41 according to the fuel injection

amount.

[0032] The controller 50, by controlling the air-fuel ratio to a predetermined rich air-fuel ratio, eliminates the sulfur poisoning of the NOx trap catalyst 10. During the elimination of sulfur poisoning, however, the controller 50 occasionally controls the air-fuel ratio to lean to perform the regeneration of the DPF 20 when the particulate matter collection amount has increased to a certain degree, thereby preventing an increase in the particulate matter collection amount of the DPF 20 due to the elimination of sulfur poisoning. When the particulate matter collection amount of the DPF 20 decreases as a result of the regeneration of the DPF 20, the air-fuel ratio is again controlled to a predetermined rich air-fuel ratio, and elimination of sulfur poisoning of the NOx trap catalyst 10 is continued.

[0033] To perform the above air-fuel ratio control, detection signals from various sensors are input to the controller 50.

[0034] These sensors include a differential pressure sensor 31 that detects the pressure difference of the exhaust gas at the inlet and outlet of the DPF 20, a λ sensor 32 which detects an excess air factor lambda (λ) of the air-fuel mixture from the oxygen concentration in the exhaust gas at the inlet of the NOx trap catalyst 10, a temperature sensor 33 which detects the inlet temperature of the DPF 20, and a temperature sensor 34 which detects the outlet temperature of the DPF 20.

[0035] Next, referring to Fig. 2, a sulfur poisoning elimination routine executed by the controller 50 will be described.

[0036] This routine is always executed during running of the diesel engine 40. Specifically, when the controller 50 terminates the routine, the following execution of the routine is started immediately or after a predetermined time

interval.

[0037] First, in a step S1, the controller 50 determines whether or not the sulfur poisoning elimination of NOx trap catalyst 10 is required. This determination is made not by directly detecting the sulfur poisoning amount of the NOx trap catalyst 10, but based on running data such as the vehicle travel distance, the fuel consumption and the travel time after the latest sulfur poisoning elimination. If it is determined that sulfur poisoning elimination of the NOx trap catalyst 10 is not required, the routine is terminated without further processing.

[0038] When it is determined that sulfur poisoning elimination of NOx trap catalyst 10 is required, the controller 50 performs the processing of a step S2 and further steps.

[0039] In the step S2, the controller 50 executes air-fuel ratio control to eliminate sulfur poisoning by using a subroutine shown in FIG. 3.

[0040] Referring to FIG. 3, the controller 50, in a step S21, determines whether or not the excess air factor λ of the air-fuel mixture detected by the λ sensor 32 is 1.0 or less. If the excess air factor λ of the air-fuel ratio is 1.0 or less, it means that the air-fuel ratio is equal to or richer than the stoichiometric air-fuel ratio.

[0041] If, as a result of this determination, the excess air factor λ is not 1.0 or less, i.e., the air-fuel ratio is lean, the controller 50, in a step S22, decreases the excess air factor λ. This is done by decreasing the opening of the intake throttle 41 by a fixed amount. After the processing of the step S22, the controller 50 repeats the determination of the step S21. Thus, the controller 50 repeats the processing of the steps S21 and S22 until the excess air factor λ becomes 1.0 or less.

[0042] When the excess air factor λ becomes 1.0 or less, the controller 50 performs the processing of a step S23.

[0043] In the step S23, the controller 50 determines whether or not the excess air factor λ is larger than 0.95. When, as a result of this determination, the excess air factor λ is not larger than 0.95, the controller 50, in a step S24, increases the excess air factor λ. This is done by increasing the opening of the intake throttle 41 by a fixed amount. After the processing of the step S24, the controller 50 repeats the determination of the step S23. Hence, the controller 50 repeats the processing of the step S23 and S24 until the excess air factor λ exceeds the value of 0.95.

[0044] When the excess air factor λ becomes larger than 0.95 in the step S23, the controller 50 terminates the subroutine.

[0045] Due to the execution of this subroutine, the excess air factor λ is controlled to within a range that is less than 1.0 and larger than 0.95.

[0046] Referring again to FIG. 2, after controlling the excess air factor λ to within a range that is less than 1.0 and larger than 0.95 in the step S2, the controller 50, in a step S3, determines whether or not regeneration of the DPF 20 is required. This determination is performed by comparing the pressure difference between the inlet and outlet of the DPF 20 detected by the differential pressure sensor 31 with a first predetermined value.

[0047] Particulate matter which has collected in the DPF 20 is an obstacle to the flow of exhaust gas, and leads to pressure loss in the exhaust gas energy. As a result, the pressure difference between the inlet and outlet of the DPF 20 increases. The controller 50 determines that when this difference exceeds the first predetermined value, regeneration of the DPF 20 is required.

[0048] This first predetermined value is a value that is a predetermined amount larger than the pressure difference when the determination result of the step S1 is affirmative for the first time, i.e., the pressure difference when air-fuel ratio control to eliminate sulfur poisoning starts.

[0049] When it is determined in the step S3 that regeneration of the DPF 20 is not required, the controller 50 repeats the processing of the step S2 and step S3 until regeneration of the DPF 20 is required. In other words, until it is determined in the step S3 that regeneration of the DPF 20 is required, the excess air factor λ of the air-fuel mixture has a value within a range less than 1.0 and larger than 0.95, which corresponds to a rich air-fuel ratio.

[0050] As a result, sulfur oxides (SOx) which have collected in the NOx trap catalyst 10 are oxidized by reducing agent components in the exhaust gas increased by the rich air-fuel ratio, and elimination of the sulfur poisoning of the NOx trap catalyst 10 takes place.

[0051] On the other hand, when the reducing agent concentration in the exhaust gas increases, the particulate matter generation amount also increases.

[0052] As a result, in the step S3, when it is determined that regeneration of the DPF 20 is required, the controller 50, in a step S4, performs air-fuel ratio control to regenerate the DPF 20 using a subroutine shown in FIG. 4.

[0053] Referring to FIG. 4, the controller 50, firstly in a step S41, determines whether or not the excess air factor λ is larger than 1.05.

[0054] If the excess air factor λ is not larger than 1.05, in a step S42, the excess air factor λ is increased. This processing is performed by increasing the opening of the intake throttle 41 by a fixed amount. After the processing of the step S42, the controller 50 repeats the determination of the step S41. In this way,

the controller 50 repeats the processing of the steps S41 and S42 until the excess air factor λ is larger than 1.05.

[0055] When the excess air factor λ becomes larger than 1.05, the controller 50 performs the processing of a step S43.

[0056] In the step S43, the controller 50 determines whether or not the excess air factor λ is less than 1.1.

[0057] If the excess air factor λ is not less than 1.1 the controller 50, in a step S44, decreases the excess air factor λ. This processing is performed by decreasing the opening of the intake throttle 41 by a fixed amount. After the processing of the step S44, the controller 50 repeats the determination of the step S43.

[0058] In this way, the controller 50 repeats the processing of the steps S43 and 44 until the excess air factor λ becomes less than 1.1.

[0059] When the excess air factor λ becomes less than 1.1 in the step S43, the controller 50 terminates the subroutine.

[0060] Due to the execution of this subroutine, the excess air factor λ is controlled to a range larger than 1.5 and less than 1.1.

[0061] Referring again to FIG 2, after the excess air factor λ is controlled to a range larger than 1.05 and less than 1.1 in the step S4, the controller 50, in a step S5, determines whether or not regeneration of the DPF 20 is complete. This is done by comparing the pressure difference between the inlet and outlet of the DPF 20 detected by the differential pressure sensor 31 with a second predetermined value.

[0062] When the particulate matter is burnt and is removed from the DPF 20, the exhaust gas flow resistance of the DPF 20 decreases, and the exhaust gas

energy loss also decreases. As a result, the pressure difference between the inlet and outlet of the DPF 20 decreases. When the pressure difference drops below the second predetermined value, the controller 50 determines that regeneration of the DPF 20 is complete. The second predetermined value is set equal to the pressure difference when the determination result of the step S1 is affirmative for the first time, i.e., the pressure difference when air-fuel ratio control to eliminate sulfur poisoning starts.

[0063] Here, the basic concept of setting the first predetermined value and second predetermined value will be described. The regeneration control of the DPF 20 performed during this routine has the purpose of preventing increase of particulate matter collected in the DPF 20 due to the sulfur poisoning elimination control of the NOx trap catalyst 10. In other words, it is different from the ordinary regeneration control of the DPF 20 which effectively makes the particulate matter collection amount zero.

[0064] Therefore, the difference between the first predetermined amount and second predetermined amount may be set to be narrower than during ordinary regeneration control, and by burning particulate matter a little at a time within a short interval, excessive temperature rise of the DPF 20 is prevented.

[0065] If regeneration of the DPF 20 is not complete in the step S5, the controller 50 repeats the processing of the steps S4 and S5. In other words, the excess air factor λ is maintained within a range larger than 1.5 and less than 1.1, i.e., corresponding to a lean air-fuel ratio. As a result, the oxygen due to the lean air-fuel ratio promotes combustion of the particulate matter, and regeneration of the DPF 20 continues.

[0066] If it is determined in the step S5 that regeneration of the DPF 20 is

complete, the controller 50, in a step S6, determines whether or not sulfur poisoning elimination is complete. This determination is performed by determining whether or not the total execution time of air-fuel ratio control for eliminating sulfur poisoning from the starting of the routine, i.e., the total continuation time of the air-fuel ratio state where the excess air factor λ is less than 1.0 and more than 0.95, has reached a predetermined time.

[0067] If the elimination of sulfur poisoning is not complete, the controller 50 repeats the processing of the steps S2-S6. When it is determined that the elimination of sulfur poisoning is complete, the controller 50 terminates the routine.

[0068] Next, referring to FIGs. 5A-5E, the variation of the excess air factor λ, sulfur poisoning amount and particulate matter collection amount due to execution of the above routine will be described.

[0069] At a time *t11*, if it is determined in the step S1 that the elimination of sulfur poisoning of the NOx trap catalyst 10 is required, the air-fuel ratio control to eliminate sulfur poisoning of the step S2 starts, and the excess air factor λ of the engine 40 is controlled to a rich air-fuel ratio region between 0.95 and 1.0 as shown in FIG. 5C. As a result, the sulfur poisoning amount falls as shown in FIG. 5D, and as the particulate matter discharge amount increases due to the rich air-fuel ratio, the particular matter collection amount of the DPF 20 increases as shown in FIG. 5E.

[0070] Here, FIGs. 5D and 5E respectively show the sulfur poisoning amount of the NOx trap catalyst 10 and particulate matter collection amount of the DPF 20 as percentages.

[0071] Regarding the sulfur poisoning amount, the poisoning amount when

it is determined that elimination of poisoning is required, is taken as 100%, and the poisoning amount when the total execution time of the air-fuel ratio control for eliminating sulfur poisoning has reached the predetermined time, is taken as 0%.

[0072] Regarding the particulate matter collection amount, the state where the particulate matter trap ability of the DPF 20 is saturated, is taken as 100%, and the state where particulate matter has not collected in the DPF 20, is taken as 0%.

[0073] At a time *t12*, when the particulate matter collection amount has reached a value corresponding to the aforesaid first predetermined value, it is determined in the step S3 that regeneration of the DPF 20 is required. As a result, the air-fuel ratio control to regenerate the DPF 20 of the step S4 is performed, and the excess air factor λ of the engine 40 is controlled to a lean air-fuel ratio region where the excess air factor λ is between 1.05 and 1.1, as shown in FIG. 5C.

[0074] Due to this control, combustion of particulate matter which has collected in the DPF 20 is promoted as shown in FIG. 5E, and regeneration of the DPF 20 is performed. At a time *t13*, when the particulate matter collection amount in the DPF 20 decreases to a value corresponding to the aforesaid second predetermined value, it is determined that regeneration of the DPF 20 in the step S5 is complete. Next, it is determined whether or not elimination of sulfur poisoning in the step S6 is complete.

[0075] At the time *t13*, the elimination of sulfur poisoning is not complete as shown in FIG. 5D. Therefore, the air-fuel ratio control to eliminate sulfur poisoning of the step S2 is repeated.

[0076] Due to the air-fuel ratio control to regenerate the DPF 20, when the

particulate matter collected in the DPF 20 burns, the combustion heat is transmitted to the NOx trap catalyst 10, and the temperature of the NOx trap catalyst 10 rises. This temperature rise of the NOx trap catalyst 10 has a favorable effect when promoting reduction of SOx in the NOx trap catalyst 10, on the next occasion when air-fuel ratio control is performed to eliminate sulfur poisoning.

[0077] In this way, by repeating air-fuel ratio control to eliminate sulfur poisoning and air-fuel ratio control to regenerate the DPF 20, the sulfur poisoning rate becomes zero, as shown in FIG. 5D.

[0078] Each time air-fuel ratio control to regenerate the DPF 20 is terminated, the controller 50 determines whether or not elimination of sulfur poisoning in the step S6 is complete. At a time *t14*, when it is determined that elimination of sulfur poisoning is complete, the controller 50 terminates the routine.

[0079] The interval when sulfur poisoning elimination control is ON from the time *t11* to the time *t14* of FIG. 5A, corresponds to the effective routine execution period. Within the interval when sulfur poisoning elimination control is ON, air-fuel ratio control to eliminate sulfur poisoning and air-fuel ratio control to regenerate the DPF 20 are repeatedly performed in alternation.

[0080] As a result, at the time *t14*, sulfur poisoning is completely eliminated, and at the same time, the particulate matter collection amount in the DPF 20 is maintained at substantially the same level as at the time *t11*. Due to this control, sulfur poisoning elimination is performed without increasing the particulate matter collection amount.

[0081] The air-fuel ratio control to regenerate the DPF 20 shown in FIGs. 5B and 5C is performed to prevent the particulate matter collection amount of the DPF 20 from increasing due to elimination of sulfur poisoning as described above.

Ordinary regeneration control of the DPF 20 is performed by a separate routine.

[0082] Next, referring to FIG. 6, a second embodiment of this invention will be described.

[0083] The exhaust gas purification device according to this embodiment comprises a fuel injector 42 upstream of the NOx trap catalyst 10 in the exhaust pipe 22. The fuel injector 42 injects fuel according to a signal from the controller 50 in an identical way to the fuel injector 44. The remaining features of the construction relating to the hardware of the exhaust gas purification device are identical to those of the first embodiment shown in FIG. 1.

[0084] As in the first embodiment, the controller 50 performs elimination of sulfur poisoning of the NOx trap catalyst 10 by the routine of FIG. 2 and the subroutines of FIGs. 3 and 4.

[0085] However, in this embodiment, the operation of decreasing the excess air factor λ in the step S22 of FIG 3 and the step S44 of FIG. 4, is performed by a fuel injection from the fuel injector 42. By injecting fuel into the exhaust gas, reducing agent components in the exhaust gas are increased, and as a result, the same exhaust gas composition as when the excess air factor λ in the air-fuel mixture falls, is obtained.

[0086] In the same way, the operation of increasing the excess air factor λ in the step S24 of FIG. 3 and the step S42 of FIG. 4 is performed by stopping the fuel injection by the fuel injector 42. By stopping injection of fuel which was injected into the exhaust gas, reducing agent components in the exhaust gas decrease, and as a result, the same exhaust gas composition as when the excess air factor λ in the air-fuel mixture increases, is obtained.

[0087] In this embodiment, by injecting fuel directly into the exhaust gas,

the reducing agent component concentration of the exhaust gas can be more precisely controlled. The air-fuel ratio of the air-fuel mixture supplied to the engine 40 is not changed, so sulfur poisoning elimination control of the NOx trap catalyst 10 can be performed without affecting the combustion of the engine 40 and without causing any fluctuation of the output torque of the engine 40.

[0088] Next, a third embodiment of this invention will be described referring to Fig. 7.

[0089] The exhaust gas purification device according to this embodiment comprises an exhaust throttle 43 downstream of the DPF 20 of the exhaust pipe 22. The exhaust throttle 43 has an opening which can be varied according to a signal from the controller 50.

[0090] When the opening of the exhaust throttle 43 is decreased, the exhaust gas pressure rises, and as a result, the EGR rate increases. When the EGR rate increases, the proportion of fresh air in the intake air amount of the engine 40 decreases, so the excess air factor λ decreases.

[0091] On the other hand, if the opening of the exhaust throttle 43 increases, the exhaust gas pressure decreases, and as a result, the EGR rate decreases. When the EGR rate decreases, the proportion of fresh air in the intake air amount of the engine 40 increases, so the excess air factor λ increases.

[0092] The remaining features relating to the hardware of the exhaust gas purification device are identical to those of the first embodiment shown in FIG. 1.

[0093] The controller 50, by repeating the routine of FIG. 2 and the subroutines of FIGs. 3 and 4 as in the first embodiment, performs elimination of the sulfur poisoning of the NOx trap catalyst 10.

[0094] However, the operation of decreasing the excess air factor λ in the

step S22 of FIG. 3 and the step S44 of FIG. 4 is performed by decreasing the opening of the exhaust throttle 43. The operation of increasing the excess air factor λ in the step S24 of FIG. 3 and the step S42 of FIG. 4 is performed by increasing the opening of the exhaust throttle 43.

[0095] According to this embodiment, elimination of the sulfur poisoning of the NOx trap catalyst 10 can be performed without varying the fuel injection amount.

[0096] Next, a fourth embodiment of this invention will be described.

[0097] The hardware construction of the exhaust gas purification device according to this embodiment is identical to that of the first embodiment, and the performing of the routine of FIG. 2 and subroutines of FIGs. 3 and 4 is identical to the first embodiment.

[0098] However, according to this embodiment, a post-injection is performed by the fuel injector 44 after the fuel injection for ordinary combustion. The operation of decreasing the excess air factor λ in the step S22 of FIG. 3 and the step S44 of FIG. 4 is performed by increasing the post-injection amount. The operation of increasing the excess air factor λ in the step S24 of FIG. 3 and the step S42 of FIG. 4 is performed by decreasing the post-injection amount.

[0099] In this way, by controlling the excess air factor λ by increasing or decreasing the post-injection amount, the control response and precision can be improved.

[0100] Next, a fifth embodiment of this invention will be described referring to FIGs. 8A-8E.

[0101] The hardware construction of the exhaust gas purification device according to this embodiment is identical to that of the first embodiment, and the

performing of the routine of FIG. 2 and subroutines of FIGs. 3 and 4 is identical to the first embodiment.

[0102] However, according to this embodiment, the determination as to whether or not regeneration of the DPF 20 is complete performed in the step S5 of FIG. 2, is performed according to the continuation time of the regeneration control of the DPF 20, i.e., the time from a time *t22* to a time *t23* in the figure, without referring to the differential pressure detected by the differential pressure sensor 31. When the continuation time of the regeneration control of the DPF 20 reaches a predetermined time, the controller 50 determines that regeneration of the DPF 20 is complete.

[0103] According to this embodiment, if the predetermined time is set to be long, the particulate matter collection amount of the DPF 20 can be reduced by a larger amount. During regeneration of the DPF 20, sulfur poisoning of the NOx trap catalyst takes place, so if the predetermined time is set to be long, it is preferred to set the continuation time of the elimination of sulfur poisoning overall, i.e., the time from a time *t21* to a time *t24*, to be long.

[0104] Next, referring to FIGs. 9A-9E, a sixth embodiment of this invention will be described.

[0105] The hardware construction of the exhaust gas purification device according to this embodiment is identical to that of the first embodiment, and the routine of FIG. 2 and subroutines of FIGs. 3 and 4, are identical to those of the first embodiment.

[0106] However, according to this embodiment, the determination of whether or not to perform regeneration of the DPF 20 performed in the step S3 of FIG. 2, and the determination as to whether or not regeneration of the DPF 20 is complete

performed in the step S5, are different from the first embodiment.

[0107] Specifically, in the step S3, it is determined that regeneration of the DPF 20 is required when the particulate matter collection rate reaches 100%. When, in the step S5, the particulate matter collection rate reaches 0%, it is determined that regeneration of the DPF 20 is complete. These conditions are equivalent to setting the first predetermined value to correspond to 100% and the second predetermined value to correspond to 0% in the first embodiment.

[0108] When the conditions of the step S3 and step S5 are set in this way, the minimum occurrence of DPF regeneration is realized during the routine execution period from the time *t31* to the time *t34*.

[0109] As a result, as shown in FIG. 9C, the variation frequency of the excess air factor λ is largely reduced compared to the first embodiment, so the effect of sulfur poisoning elimination on the running of the engine 40 can be reduced.

[0110] The contents of Tokugan 2002-377232, with a filing date of December 26, 2002 in Japan, are hereby incorporated by reference.

[0111] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, within the scope of the claims.

[0112] For example, the second-fourth embodiments relating to the means of increasing/decreasing the excess air factor λ, and the fifth and sixth embodiments relating to criteria for regenerating the DPF 20, may be performed in any combination.

[0113] The embodiments of this invention in which an exclusive property or privilege is claimed are defined as follows: